Flow from Dry Ice Disrupted

Flow Visualization: The Physics and Art of Fluid Flow

MCEN 4151

Assignment 1: Get Wet

By Ben Healy

Prof. Jean Hertzberg

This photograph was taken for the first assignment, Get Wet, in the University of Colorado's Flow Visualization course. The intent of this individual assignment was to get the student's feet wet in photography and flow visualization. For this image I attempted to capture the transition from laminar to turbulent flow.

Capturing this image was accomplished with a relatively simple setup. Figure 1, below, shows the setup which consisted of placing a 2 pound block of dry ice in a brown paper grocery bag resting on its side, and then setting the bag on a counter to allow the condensate to flow out of the bag. The condensate was lighted from below with a Petzl headlamp (1 white LED powered by 3 AAA batteries). The photograph was taken at night with all other lights turned off. A flathead screwdriver was placed in the laminar flow to disrupt it. The camera was held almost directly above the flow. The condensate flow in this image is about 5 inches across.

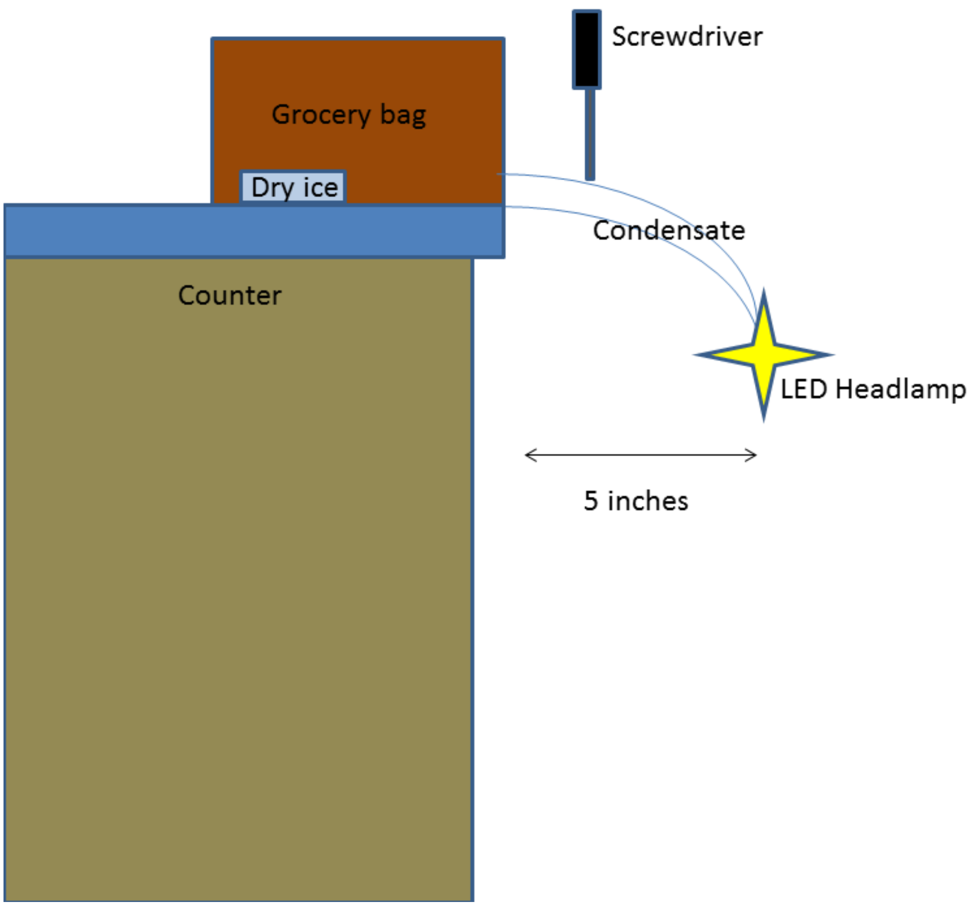

Figure 1: Diagram of *Flow from Dry Ice Disrupted*

The Reynolds number was calculated as $Re = \frac{UD}{v} = \frac{\left(0.1\,\frac{m}{s}\right)(0.127\ m\,)}{0.119\,\frac{m^2}{s}}$ = 0.107. The velocity of 0.1 m/s was chosen by visual estimation; it was not measured empirically. This Reynolds value puts the flow firmly in the laminar region, which makes sense. The flow was perfectly laminar until a flathead screwdriver was placed in the flow to disrupt it and turn it into a turbulent flow. The flow in the image is driven by buoyant forces. As the solid carbon dioxide sublimates in the room temperature air, it remains quite cold. The CO_2 is so cold that it condenses water vapor out of the air. The cold CO_2 is denser than the warm air and sinks to the ground, condensing water on its way down. In the image this looks like a small cloud is being poured out onto the ground. The flow is slow and the absence of strong air currents in the room created a very smooth laminar flow of water vapor. The flow around the flat screwdriver face becomes turbulent. An area of higher pressure is built up on the front of the screwdriver as the CO2 collides with it and then proceeds to flow around the screwdriver face to the backside of the screwdriver (an area of lower pressure). The turbulence is a result of streams of differing velocities coming into contact with each other. Solving the Navier-Stokes equations leads to a mathematical model of what is happening and the paper, "Large Eddy Simulation of Wing Tip Vortex in the Near Field," by Jiang et al, does a good job of describing it.[1, 2]

The image was captured using a Nikon D3200 digital SLR. The field of view crop factor is 1.5, as the D3200 is not a full-frame camera. The distance from the object to the lens was roughly two feet. The lens used was a Nikon 18-55 mm – F/3.5-5.6 G Nikon AF-s DX VR. The exposure was made with an aperture of f/5.6, shutter speed of 1/60 s, and 6400 ISO. The original image was 6016x 4000 pixels. The final image was cropped to 5307x 3553 pixels. No other post-processing was done to the image.

This image reveals that flows similar to wing tip vortices can occur at very low velocities. I like the shallow depth of field in this photo because it shows that the flow is flowing away from the viewer as they look down on it. I feel the physics are shown well as the flow goes around the screwdriver blade. I achieved my intent in showing the flow going from laminar to turbulent. It shows the direction of flow nicely. I wish I had used a stronger light source so that I could drop the ISO down from 6400 and eliminate some of the graininess in the image. I also would have liked to have disrupted the flow from below instead of above to hide the rest of the screwdriver. I think this idea could be taken further by investigating different flow velocities and different airfoil shapes. It would be interesting to compare the flow in these situations and relate them to the physics behind it.

References

1. Li, Jiang. "Department of Mathematics." University of Texas at Arlington. University of Texas, n.d. Web. 11 Feb 2014. <http://www.uta.edu/math/preprint>.
2. Wikipedia contributors. "Navier-Stokes Equations." Wikipedia, The Free Encyclopedia.